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Calcium Sulphide for the Control of Apple and Peach Diseases



BY

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CALCIUM SULPHIDE FOR THE CONTROL OF APPLE AND PEACH DISEASES¹

By R. H. Hurt and F. J. Schneiderhan²

The purpose of this bulletin is to present the results of three years of study with calcium sulphide, a new and promising fungicide for controlling diseases of both apples and peaches. Most of the fungicides in use at present cause injury to fruit and foliage in some years under certain weather conditions and to obviate this trouble as far as possible, the present study was begun in 1926. There has been a need for new fungicides with proper toxicity for fruit disease control, but less of the caustic properties which have caused injury to both fruit and foliage in Virginia orchards and those of other states. There has been a further need for a fungicide which could be applied to apples throughout the spray season instead of using lime-sulphur in the early season and changing to Bordeaux mixture in the late season. Dry-mix has largely replaced self-boiled lime-sulphur as a spray for peaches, but there has been some complaint about dry-mix because in certain years it has been known to cause injury to both fruit and foliage of peach trees. The data presented in this bulletin, although preliminary in nature, indicate that calcium sulphide (calcium monosulphide, hereafter called calcium sulphide) is a material which is remarkably free of caustic properties, has high toxicity to plant pathogens, and is easily handled in the orchard when properly ground and screened. It also has the unusual advantage of being applicable to both apples and peaches. There are, however, certain disadvantages involved in the use of calcium sulphide, chief of which is the necessity of adding considerable bulk of more or less solid matter to a spray solution. No doubt this increases wear on machinery. Furthermore, unless this material is properly ground and screened at the factory, serious trouble from clogging of spray nozzles is sure to follow.

The investigations of calcium sulphide as a fungicide were conducted by the Virginia Agricultural Experiment Station at its two field laboratories, located at Staunton and Winchester.

DESCRIPTION AND PREPARATION OF CALCIUM SULPHIDE

The material used in these investigations was a preparation composed of calcium sulphide as the active ingredient, dehydrated calcium sulphate and the reducing agent in varying amounts. The material used in the experimental work in 1926 and 1927 was the U. S. Pharmacopeial preparation containing 60 per cent. calcium sulphide (CaS), dehydrated calcium sulphate, charcoal and starch in varying amounts. The above material is used by the drug trade and is known as crude calcium sulphide. It is a preparation formerly known as sul-

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phurated lime (Calx sulphurata), but the present designation is more in keeping with its true character since the U. S. Pharmacopoeia requires it to contain not less than 55 per cent. of calcium sulphide (CaS), together with calcium sulphate, charcoal and starch in varying amounts. It may, however, contain a much higher percentage of calcium sulphide, depending upon the extent of reduction of the calcium sulphate used in its preparation. The fungicidal value of this new fungicide has been found to depend upon the percentage of calcium sulphide present in the mixture, which increases in efficiency as the percentage of calcium sulphide is increased. The U. S. P. preparation occurs as a pale grayish or yellowish powder, only very slightly soluble in water and of a fineness that approximately 95 per cent. will pass through a 200- to 300-mesh sieve.

The material used in the tests during 1928 was a commercial product containing approximately 65 per cent. of calcium sulphide (CaS), the remainder being unreduced calcium sulphate and powdered coal which was used in the reduction process. This material was very much darker in color and coarser in texture than the U. S. P. preparation; however, it gave equally as good control in less quantity, and the dark color was no disadvantage.

Calcium sulphide is manufactured from anhydrous calcium sulphate by reduction with charcoal and starch or with powdered coal alone in a reverberatory furnace at a temperature of approximately 1800 degrees F. Calcium sulphate in the anhydrous form occurs naturally in certain deposits in Virginia, but the ordinary hydrated calcium sulphate from which this material may be prepared has a wide distribution in the United States and Canada. Obviously, the fruit grower cannot prepare his own material but must depend upon some chemical manufacturing plant for it.

A variation of CaS content from 60 to 65 per cent. occurred in the calcium sulphide used in 1926, 1927 and 1928. In order to standardize the amount of this material to be used in a certain unit of water, 50 gallons for example, it is manifest that the CaS content must first be standardized at the manufacturing plant, which may be accomplished with very little difficulty in spite of the fact that a variation in CaS content is found in different batches as they come from the reduction furnace.

We shall see later in this bulletin that calcium sulphide has strong fungicidal properties. It is not known to the writers at this time whether this toxicity to fungi is due entirely to the sulphur which is liberated when CaS comes in contact with moisture or whether it is due partially to the calcium hydrosulphide formed by hydrolysis. Studies now in progress have for their object the determination of the toxic factors involved.

The discussion will treat of calcium sulphide from two standpoints, its toxicity to fungi, and its non-caustic properties when applied to both apples and peaches under weather conditions prevailing during the spraying season in Virginia for the past three years. Although the main emphasis of this study has been given to the fungicidal effectiveness of the material, extensive observations of its non-caustic properties have also been made.

EXPERIMENTAL RESULTS ON DISEASE CONTROL

The most important fungous disease of the apple in the United States is apple scab caused by *Venturia inaequalis*, Cook, Winter, and the two most important diseases of the peach are scab (*Cladosporium carpophilum*, Thum.) and brown rot (*Sclerotinia cinerea*, (Bon.) Schröt.). Attention is called at this time to the excellent conditions under which this new fungicide was tested, namely, an

incidence of nearly 100 per cent. of apple scab in most of the tests and heavy infection by peach scab. We shall see that calcium sulphide has good fungicidal properties, for we were able to secure very good disease control under severe conditions of infection on both apples and peaches.

SPRAYING EXPERIMENTS IN 1926

Experimental work was begun in a limited manner by the senior author at the Staunton field laboratory in 1926. Several Winesap apple trees in the Mary Baldwin orchard and several Elberta peach trees in the Hinkel orchard were sprayed with the U. S. P. preparation of calcium sulphide, containing approximately 60 per cent. CaS. The fungicide was applied with a large hand sprayer. The apples were sprayed in the pink, calyx, 3-weeks, and 5-weeks stages with calcium sulphide at the rate of 8 pounds to 50 gallons of water. Lead arsenate was used at the rate of 1 pound to 50 gallons of the suspension in all except the pink application. The peaches were sprayed with lead arsenate and lime in the shuck stage, and with calcium sulphide at the rate of 8 pounds to 50 gallons of water on June 1 and July 15. The results of these experiments are shown in Tables 1 and 2.

TABLE 1.—Results of spraying winesap apples with calcium sulphide in 1926. Data obtained at harvest, October 20.

Plat	Num- ber fruits in test	PERCENTAGE OF FRUIT						
		Clean	Scab infected	Cloud infected	Bitter rot infected	Wormy	Frost injured	Curculio infested
Calcium sulphide.....	280	74.28	0.35	1.75	0.71	21.35	2.10	0.00
Check, unsprayed.....	200	18.00	26.00	38.50	4.00	39.50	7.00	0.50

TABLE 2.—Results of spraying Elberta peaches with calcium sulphide in 1926. Data obtained at harvest, September 20.

Plat	Number fruits in test	PERCENTAGE OF FRUIT	
		Clean	Scab infected
Calcium sulphide.....	1,027	99.60	0.39
Check, unsprayed.....	214	60.74	39.26

From the limited number of fruits examined, the fungicidal value of calcium sulphide is manifest. While 26 per cent. of scab in the check is not a heavy infection, the new fungicide has reduced this infection to a trace. Cloud infection was reduced from 38 per cent. to 1.75 per cent. in the sprayed trees. A slight reduction of bitter rot is also evident even though sulphur fungicides are not ordinarily considered to be very toxic to the bitter rot fungus. Peach scab according to data in Table 2 was very satisfactorily controlled by calcium sulphide.

SPRAYING EXPERIMENTS IN 1927

The spraying experiments on apples in 1927 were conducted in J. W. Quick's orchard, Crozet, Virginia, under conditions of very severe scab infection. Two varieties of apples, Winesap and Delicious, were sprayed. The experiment on peaches was conducted in the Brown orchard, Crozet, Virginia, on the Belle of

Georgia variety. Conditions in this orchard were favorable for a fairly heavy infection by peach scab.

These tests were carried out on a much larger scale than in 1926, blocks of about twenty trees being used in the commercial orchards above mentioned and regular orchard spraying equipment being used to make the applications. The recommended practice among fruit growers in this section is to use lime-sulphur, 1 part to 40 parts of water, in the first three summer sprays, followed by two applications of Bordeaux mixture. This spray program is used in the Piedmont section of Virginia to prevent the severe spray injury invariably following the use of lime-sulphur in hot weather, which usually begins about the time of the 5-weeks spray.

In the 1927 experiments, one block of Winesap apples was sprayed with U. S. P. crude calcium sulphide at the rate of 12.5 pounds in 50 gallons of water in the pink (March 28), petal fall (April 25), and 3-weeks (May 12) sprays; and Bordeaux mixture, 3-5-50, in the 5-weeks (June 5) and 7-weeks (July 3) sprays. Another block of Winesap trees was sprayed with lime-sulphur, 1 to 40, in the first three sprays and Bordeaux mixture, 3-5-50, in the last two. Lead arsenate, at the rate of 1 pound to 50 gallons, was used on both blocks in all except the pink spray. A third block of unsprayed trees in the same orchard was used as a check. In another section of this same orchard a similar experiment was conducted on Delicious apples. The spray applications were made on the dates given above and the materials used were the same, except that 8 pounds of calcium sulphide to 50 gallons of water were used instead of 12.5 pounds. The results of these experiments are shown in Tables 3 and 4.

The data in both Tables 3 and 4 seem to be satisfactory evidence of the toxicity of calcium sulphide to the apple scab fungus. This toxicity is also demonstrated by the condition of the fruit shown in Figure 1. The fruit from the checks was a total loss, as shown in Figure 2. It was more severely infected by scab than any fruit from check trees observed by either of the writers during a period of six years. It is evident that 12.5 pounds of calcium sulphide of U. S. P.

TABLE 3.—Comparative results obtained by spraying Winesap apples with calcium sulphide and lime-sulphur in the first three sprays in 1927.

Plat	Num- ber fruits in test	PERCENTAGE OF FRUIT					
		Clean	Scab infected	Wormy	Curculio infested	Spray injured	Cloud infected
Calcium sulphide 3 sprays, Bordeaux 2 sprays.....	3,000	93.06	4.76	1.53	0.30	0.00	0.00
Lime-sulphur 3 sprays, Bordeaux 2 sprays.....	3,000	80.86	10.59	2.16	1.23	0.10	0.00
Check, unsprayed.....	500	0.00	100.00	6.00	3.00	0.00	0.10

PERCENTAGE OF FRUIT IN RESULTING GRADES

Plat	Fancy	No. 1	No. 2	Culls
Calcium sulphide 3 sprays, Bordeaux 2 sprays.....	12.53	75.83	9.49	2.15
Lime-sulphur 3 sprays, Bordeaux 2 sprays.....	6.86	74.00	9.92	9.22
Check, unsprayed.....	0.00	0.00	0.00	100.00

TABLE 4.—Comparative results obtained by spraying Delicious apples with calcium sulphide and lime-sulphur in the first three sprays in 1927.

Plat	Num- ber fruits in test	PERCENTAGE OF FRUIT				
		Clean	Scab infected	Wormy	Spray injured	Cloud infected
Calcium sulphide 3 sprays, Bordeaux 2 sprays.....	3,000	74.96	13.63	5.43	0.00	0.00
Lime-sulphur 3 sprays, Bordeaux 2 sprays.....	3,000	75.83	11.53	3.13	0.63	0.00
Check, unsprayed.....	508	0.00	100.00	15.63	0.00	0.38

PERCENTAGE OF FRUIT IN RESULTING GRADES

Plat	Fancy	No. 1	No. 2	Culls
Calcium sulphide 3 sprays, Bordeaux 2 sprays.....	14.30	60.83	7.02	18.02
Lime-sulphur 3 sprays, Bordeaux 2 sprays.....	7.96	68.53	9.62	13.89
Check, unsprayed.....	0.00	0.00	0.00	100.00

strength to 50 gallons of water is considerably more effective for scab control than the standard concentration of lime-sulphur used for summer spraying. The superiority of the calcium sulphide is indicated by the scab percentages of 4.76 and 10.29, respectively, for the calcium sulphide and lime-sulphur plats. Comparing the results obtained on Delicious apples in Table 4 with those in Table 3 we infer that 8 pounds of calcium sulphide in 50 gallons of water is not as effective for scab control as 12.5 pounds and does not give the control of this disease that lime-sulphur does. The advantage of lime-sulphur over the 8 pounds in 50 concentration of calcium sulphide is indicated by the scab occurrence in the calcium sulphide and the lime-sulphur plats, which is 13.63 and 11.56 per cent., respectively. This is not considered to be satisfactory commercial control even under the conditions of extremely severe infection, as indicated by 100 per cent. of scab in the check. The fruit free from injury in Table 4, calcium sulphide plat, was only about one per cent. less than that in the lime-sulphur plat, but the conditions of the foliage and the finish of the fruit in the calcium sulphide plat were very much superior to those in the lime-sulphur plat. The foliage was greener and had none of the dull appearance found in the lime-sulphur plat. The higher percentage of fancy fruit in the calcium sulphide plat is attributed to the use of calcium sulphide.

In Table 5 we present data showing the comparative value of calcium sulphide, dry-mix, and emulsoid sulphur as fungicides for peach trees. The scab infection in this block of peach trees was not as severe as desirable for the best experimental purposes but it represents an average infection for the year. This experiment was conducted in the Brown orchard at Crozet, and each block consisted of about twenty trees of the Belle of Georgia variety. All of the plats were sprayed with lead arsenate, 1 pound in 50 gallons of water, in the shuck spray. Then the calcium sulphide plat was sprayed on May 20, and again on June 16 with calcium sulphide, 12.5 pounds in 50 gallons of water; the dry-mix plat was sprayed on the same dates with dry-mix, 8 pounds in 50 gallons of water; and the emulsoid sulphur plat was sprayed on the same dates with emulsoid sulphur, 4

pounds in 50 gallons of water. The results of this experiment are given in Table 5.

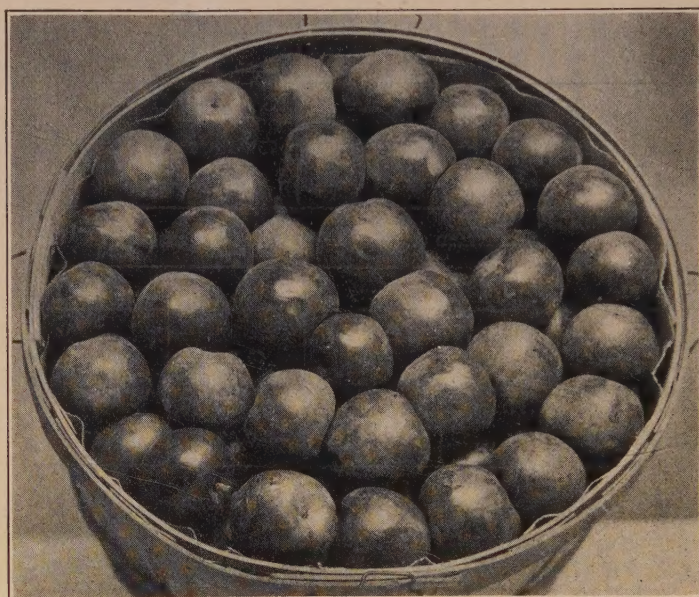


Fig. 1.—Winesap apples sprayed with calcium sulphide in the pink, petal fall and 3-weeks sprays followed by Bordeaux mixture, 3-5-50 in the 5- and 7-weeks sprays. The checks developed 100 per cent. of scab while the sprayed apples shown above had only 4.7 per cent. of scab and 93 per cent. were free from injury of any kind. (See Table 3.)

TABLE 5.—Comparative results obtained by spraying Belle of Georgia peaches with calcium sulphide, dry-mix, and emulsoid sulphur in 1927.

Plat	Number fruits in test	PERCENTAGE OF FRUITS			
		Clean	Scab infected	Wormy	Brown rot infected
Calcium sulphide.....	2,200	99.68	0.23	0.09	0.00
Dry-mix.....	510	88.04	11.96	0.09	0.00
Emulsoid sulphur.....	350	98.76	1.24	0.00	0.00
Check, unsprayed.....	600	60.01	38.83	1.00	0.16

The check was not of the Belle of Georgia variety, but Hiley Belle, maturing about two weeks earlier than Belle of Georgia. The scab infection in this check is not nearly as heavy as would have occurred in the Belle of Georgia variety, as evidenced by some unsprayed trees of this variety nearby, where the infection was between 90 and 100 per cent. The superiority of calcium sulphide over dry-mix and emulsoid sulphur is shown by the data in Table 5. The calcium sulphide

block had the slightest infection and was followed in order by emulsoid sulphur, and dry-mix. It is not considered that 11.96 per cent. of peach scab in sprayed



Fig. 2.—Unsprayed Winesap apples from the check in the same row sprayed with calcium sulphide. These apples have 100 per cent. scab infection and all of them are culls. (See Table 3.)

trees is satisfactory commercial control of this disease. However, this infection in the dry-mix plot was very slight on individual fruits, amounting to not more than a few lesions per peach, thus enabling these peaches to be packed as a good commercial pack.

SPRAYING EXPERIMENTS FOR DISEASE CONTROL IN 1928

The conditions for testing calcium sulphide for disease control on apples were again very satisfactory in 1928, as indicated by 100 per cent. of scab infection in the checks. The tests in 1928 were conducted on a considerably larger scale than in either 1926 or 1927. The work in 1928 was done at Staunton and Waynesboro, Virginia, in large commercial orchards. About 8 tons of calcium sulphide were used by the writers and commercial growers for testing purposes in 1928. The material used in this year was a commercial preparation containing approximately 65 per cent. CaS, a trace of hydrated lime and unreduced calcium sulphate, together with a small amount of powdered coal which gave this material a darker color than that used in the previous experiments.

In Table 6, a comparison of the effectiveness of calcium sulphide and dry-mix as scab spray materials is afforded. This experiment was conducted on Winesap apples in the Hinkel orchard at Staunton. The calcium sulphide plot was sprayed with commercial calcium sulphide, 10 pounds in 50 gallons of water,

in the pink (April 26), calyx (May 9), 3-weeks (May 28), and 5-weeks (June 18) stages. The dry-mix plat was sprayed with dry-mix, 8 pounds in 50 gallons of water, on the same dates in the first three stages, but the 5-weeks spray material (June 18) in this plat was Bordeaux mixture, 3-5-50. The results of this experiment are given in Table 6.

TABLE 6.—Comparative results obtained by spraying Winesap apples with calcium sulphide and dry-mix in 1928. Data secured at harvest, October 2.

Plat	Num- ber fruits in test	PERCENTAGE OF FRUIT					
		Clean	Scab infected	Wormy	Curculio infested	Cloud infected	Spray injured
Calcium sulphide.....	1,000	97.99	2.50	0.30	0.20	0.10	0.00
Dry-mix 3 sprays, Bordeaux 1 spray....	1,000	94.30	5.20	0.20	0.30	0.00	0.00
Check, unsprayed.....	1,000	0.00	100.00	0.10	0.50	2.60	0.00

Both the calcium sulphide and dry-mix gave very satisfactory control of scab in this very heavily infested orchard. There was approximately twice as much scab infection in the dry-mix plat as in the plat sprayed with calcium sulphide. The value of dry-mix as a spray material for apple scab control has been questioned in Virginia and other states, but the data in Table 6 seem to indicate that it is a satisfactory substitute for lime-sulphur and eliminates to a large extent the spray injury and lack of finish usually associated with the use of the latter material. With an infection of 100 per cent. in the check, the production of approximately 98 per cent. of fruit free from injury of any kind is, it would seem, good evidence of the value of calcium sulphide as a fungicide. The use of calcium sulphide throughout the spray season without any injury to either fruit or foliage also recommends this new fungicide from that important standpoint.

In Table 7, the data showing the comparison of calcium sulphide used throughout the season and lime-sulphur applied in the first three sprays followed by two Bordeaux mixture sprays, are tabulated. These data are interesting because they afford a means of comparing the effectiveness of calcium sulphide with the present standard spray materials used in the best Virginia orchards. In this test, 125 large Winesap trees were sprayed with calcium sulphide and the same number were sprayed with lime-sulphur followed by Bordeaux mixture. The spray applications were made on the same day with the same spray equipment. In the calcium sulphide plat the pink, calyx, 3-weeks, 5-weeks, and 7-weeks applications all consisted of commercial calcium sulphide, 10 pounds in 50 gallons of water. In the lime-sulphur plat the first three applications consisted of lime-sulphur, 1-40, and the last two, Bordeaux mixture, 3-5-50. The experiment was conducted on Winesap apples in the Fox Hill orchard at Staunton.

It is evident that there is considerably better scab control in the calcium sulphide plat than in the lime-sulphur plat. This superiority is represented by the scab percentages of 3.5 and 11.2 in the calcium sulphide and lime-sulphur plats, respectively. The percentage of fruit free of injury in the calcium sulphide plat was 96.2 as compared with only 87.2 in the lime-sulphur plat. Besides these noteworthy differences in scab control, an even more noticeable difference was found in the amount of spray injury. In the calcium sulphide plat there was no noticeable spray injury on either fruit or foliage. In fact both the fruit and

TABLE 7.—Comparative results obtained in two plats of Winesap apples, one of which was sprayed with calcium sulphide throughout the season, the other with lime-sulphur followed by Bordeaux mixture in the 5- and 7-weeks applications. Data secured at harvest, October 4, 1928.

Plat	Num- ber fruits in test	PERCENTAGE OF FRUIT				
		Clean	Scab infected	Wormy	Curculio infested	Cloud infected
Calcium sulphide only.....	1,000	96.20	3.50	0.20	0.10	0.00
Lime-sulphur 3 sprays, Bordeaux 2 sprays.....	1,000	87.20	11.20	1.10	0.50	0.00
Check, unsprayed.....	1,000	0.00	100.00	1.00	1.50	0.50

foliage were in excellent condition at the end of the spray season, while in the lime-sulphur plat, there was considerable spray injury as evidenced by a premature dropping of the leaves, a leathery, brownish appearance of the leaves and some russetting on the fruit. The finish of the fruit packed from the lime-sulphur plat was inferior to that in the calcium sulphide plat.

In addition to the tests made on apples in 1928, a test was made on Elberta peaches in the Foster orchard at Waynesboro. About 50 trees were sprayed with commercial calcium sulphide, 6 pounds in 50 gallons of water, on June 14 and July 20. The rest of the orchard was sprayed on the same dates with dry-mix, 8 pounds in 50 gallons of water. The results of this experiment are shown in Table 8.

TABLE 8.—Comparative results obtained by spraying Elberta peaches with calcium sulphide, and dry-mix in 1928.

Plat	PERCENTAGE OF FRUIT		
	Clean	Scab infected	Brown rot infected
Calcium sulphide.....	89.00	11.00	0.00
Dry-mix.....	90.00	10.00	0.00
Check, unsprayed.....	40.00	60.00	0.00

Slightly better control of scab was obtained in the plat sprayed with dry-mix than in the plat sprayed with calcium sulphide. The first application was made on June 14, which was about two weeks late for effective control. Scab infection had appeared previous to June 14, and therefore, the control of this disease indicated by the data in Table 8 is not what it should have been. Notwithstanding this irregularity in the spray applications, considerable control was effected. No fruit or foliage injury was found in either plat used in this test.

THE COMPARISON OF CALCIUM SULPHIDE WITH OTHER FUNGICIDES AS A CAUSE OF SPFAY INJURY IN 1927

In an orchard interplanted with Winesap, Stayman and Rome Beauty, a test to determine the relative amounts of spray injury and scab control, resulting from the application of different fungicides was begun in 1927. Reports of the successful use of dilute Bordeaux mixture and lime-sulphur throughout the season have appeared from time to time in the literature dealing with this subject. The Bordeaux mixture of the 1-1-50 formula and lime-sulphur, 1 to 60, were the

concentrations used in these reported tests from other states. In addition to the fungicides just mentioned, calcium sulphide, colloidal copper, and dry-mix were used in the tests in 1927.

Five different plats of one row each were selected and the same material was applied to each plat throughout the season. The concentrations of the different fungicides used were as follows: Colloidal copper, 2 gallons in 100 gallons of water; Bordeaux mixture, 1-1-50 formula; lime-sulphur, 1 to 60; calcium sulphide, 32 pounds in 200 gallons of water, and dry-mix 32 pounds in 200 gallons of water. These materials were applied in the pink (April 18), petal fall (May 7), 3-weeks (May 31), and 5-weeks (June 21) applications.

The apples were picked on September 23 and 2,000 fruits from each sprayed plat and the check were examined for disease infection and spray injury. The leaves of the trees were also examined throughout the season.

In Table 9 we present the data showing disease occurrence and spray injury.

TABLE 9.—Scab control and spray injury resulting from the application of five different fungicides on Winesap, Stayman, and Rome Beauty apple trees, Winchester, Virginia, 1927.

Plat	WINESAP		STAYMAN WINESAP		ROME BEAUTY	
	Scab infection	Spray injury	Scab infection	Spray injury	Scab infection	Spray injury
	<i>Per cent. t*</i>	<i>Per cent. t</i>	<i>Per cent. t</i>	<i>Per cent. t</i>	<i>Per cent. t</i>	<i>Per cent. t</i>
Calcium sulphide.....	t	t	t	t	t	t
Dry-mix.....	t	10	t	5	t	t
Colloidal copper.....	t	85	t	70	t	10
Bordeaux mixture.....	t	t	t	t	t	t
Lime-sulphur.....	15	t	8	t	12	t
Check, unsprayed.....						

*—trace

From the standpoint of scab control the results of this test are inconclusive because of the slight infection. When the check shows less than 20 per cent. of scab infection, the experimental error becomes too important a factor for conclusive results. Somewhat better results are indicated in regard to spray injury, both on the fruit and the leaves.

Both of the copper fungicides caused considerably more spray injury than the other fungicides. The only definite spray injury in the form of russetting appeared in the two plats sprayed with colloidal copper and dilute Bordeaux. Russetting was noticed ten days after spraying. Winesap apples sprayed with Bordeaux showed 85 per cent. of russet compared to 70 per cent. for Stayman apples and 10 per cent. for Rome Beauty. There appears to be a decided difference in susceptibility to russetting in these three varieties. Colloidal copper appears to be less caustic to fruit than 1-1-50 Bordeaux, but its effect on the foliage was much more injurious. Severe injury manifested by premature defoliation and marginal leaf burning was evident in this plat at mid-season. An estimate of the defoliation made by comparing the leaves on the ground beneath the trees in this plat and the other plats shows that approximately 15 per cent. more leaves dropped as a result of using this spray. Of the leaves persisting on the trees approximately 25 per cent. showed marginal burning in some degree. The Stayman leaves were injured most and were followed in order by Rome Beauty and Winesap.

In the plat sprayed with lime-sulphur, 1 to 60, no perceptible injury was noted. The fruit and foliage were in very good condition at picking time and the apples had a high finish. It is doubtful whether or not this strength of lime-sulphur is sufficiently toxic to prevent scab infection in a year when approximately 95 per cent. of the fruits from the checks are infected as was the case in this same block of trees in 1922 and 1924. Furthermore it is not known whether or not lime-sulphur of this concentration will cause russetting on a very susceptible variety like Ben Davis.

The fruit and foliage in the plat sprayed with dry-mix were somewhat better than that in the lime-sulphur plat, but the best results in condition of foliage and finish of fruit were undoubtedly found in the plat sprayed with calcium sulphide. A very slight grayish spray residue persisted on both fruit and foliage in this plat, but this residue was removed in the handling incident to picking and packing. The pickers remarked that the fruit in the calcium sulphide plat was the best in that particular section of the orchard. Their observation is of interest in this connection because they would notice only outstanding differences in the quality and finish of the fruit.

The trees used in this test have been under observation during the past seven years. In previous years when the regular Virginia spray schedule was used in this orchard, there was always a definite, and in some years, a considerable amount of russetting and leaf injury resulting probably from lime-sulphur, 1 to 40, applied in the 3-weeks spray or from 2-4-50 Bordeaux applied in the last two sprays. The condition of the leaves and foliage in the plat sprayed with calcium sulphide in 1927 was the best of the six-year period, 1922-1927, inclusive. There was not much difference in the finish of the fruit in the dry-mix and calcium sulphide plats but there was a noticeable superiority in the latter plat.

We infer from the test made in 1927 that severe russetting results from the use of Bordeaux 1-1-50 on the varieties mentioned above, under the weather conditions prevailing in 1927. It is clearly apparent that calcium sulphide is a safe fungicide to use throughout the spray season and that fruit sprayed with it will be of high finish. Colloidal copper of the type used in this test is severely injurious to foliage. Additional experimentation alone will enable us to determine the proper concentration of this new copper fungicide.

SPRAY INJURY TESTS IN 1928

Following the good results obtained with calcium sulphide and dry-mix in the tests of 1927, it was decided to again test these fungicides in 1928 on Ben Davis, the variety which is probably more susceptible to spray injury than any other commercial variety grown in Virginia. In some years when growers use lime-sulphur in the 5-weeks spray, especially when the weather is hot, russetting to the extent of 90 to 95 per cent. results. This variety has a predisposition to skin damage, usually associated with such factors as frost, sun, water, and spray material. Infrequently, check trees show a considerable percentage of russeted fruits and it is a difficult matter to determine exactly what the causes of injury are in this variety and others. Very likely the determination of all the factors involved in spray injury will have to be made by the plant physiologist, working with material under carefully controlled conditions.

Admitting that there are some unknown factors besides caustic fungicides involved in russetting of apples, the tests reported in this bulletin indicate that certain fungicides applied to apples are contributing, if not the most important causes of russetting.

A row containing 56 Ben Davis trees twenty years old was used for a test in 1928, half of the row being sprayed with calcium sulphide and the other half with dry-mix. In an adjoining row, lime-sulphur was applied up to and including the 3-weeks spray, followed by lead arsenate only, in the 5- and 7-weeks sprays. The spray applications were made on the following dates: petal-fall, May 14; 3-weeks, June 2; 5-weeks, June 25; 7-weeks, July 10. The same amounts of both dry-mix and calcium sulphide were used, namely, 32 pounds in 200 gallons of water. Six pounds of acid lead arsenate were used with both materials in each 200 gallons. The applications were made with two Boyce double guns at a pressure of approximately 375 pounds per square inch.

Two thousand apples were examined in each plat and in the checks on October 14, the apples being examined on the trees.

The results of this test can be given without tabulation. In the plat sprayed with calcium sulphide the spray injury in the form of russet amounted to 5 per cent. In the dry-mix plat it was 9 per cent. as compared with 4.5 per cent. in the check. There was very little difference in the finish of the fruit in the two plats, both being excellent, and suitable for a U. S. No. 1 pack. A trace of spray residue persisted on the fruits in the calcium sulphide plat, while none was found in the dry-mix plat, indicating, as in 1927, that calcium sulphide has slightly better adhering qualities than dry-mix.

In an adjacent row sprayed with lime-sulphur, russeted fruit amounted to 15 per cent. There was no noticeable leaf injury in the calcium sulphide and dry-mix plats, while in the lime-sulphur plat considerable defoliation had occurred. The russetting in the lime-sulphur plat was of the netted type. Very little calyx-end injury was found.

Another test was made in the Apple Ridge Orchard north of Winchester in a block of Ben Davis. The manager had used dry-mix in this orchard in previous years and in 1927 he was unable to pack any U. S. No. 1 apples on account of russetting. In 1928 he used calcium sulphide in the 3-, 5-, and 7-weeks sprays and out of a total of 262 barrels packed, 224 were U. S. No. 1 with a high finish. It was the first time in the history of this orchard that such a high percentage of No. 1 apples was packed. This grower is going to spray only with calcium sulphide in all of his orchard in 1929.

The results of these studies of various fungicides over a two-year period, indicate that calcium sulphide is a comparatively non-caustic spray material and that it can be used throughout the season on varieties susceptible to spray injury. A high finish on the fruit and a minimum of foliage injury results from the use of this new fungicide. Under Virginia conditions the copper fungicides as a rule cause injury when applied in the early season when the cool weather prevails.

METHOD OF HANDLING CALCIUM SULPHIDE IN THE ORCHARD

A suspension of this material can be easily obtained in water. The ease with which it can be mixed with water is a commendable characteristic. The required amount is weighed out and placed in the tank and the water added, or it may be washed in through the screen by the inflowing water. Calcium sulphide when first added to the water in the tank settles fairly rapidly, but it goes into suspension as soon as the agitator begins to move. The material when prepared by the U. S. P. process is usually light gray in color. The commercial material, however, is very much darker in color due to the fact that the calcium sulphate is

reduced with powdered coal. The material when in contact with moisture gives off a slight odor of hydrogen sulphide. It is a well known fact that certain spray materials like dry-mix and lead arsenate cannot be placed in a tank and permitted to settle because a putty-like mass results which cannot be dislodged by agitation and which effectively clogs the suction strainer and spray nozzles. Lead arsenate in paste form can be put into the spray tank either before or after the calcium sulphide. There is not the characteristic reaction between calcium sulphide and lead arsenate as with lime-sulphur and lead arsenate in which soluble arsenic results; therefore, it is not necessary to use extra lime with calcium sulphide and lead arsenate. This preparation does not deteriorate when kept in a dry place. There is a tendency to form a crust when it is stored in a damp place, but this does not occur when the containers are kept tight in a dry storage.

SUMMARY

The material designated in this bulletin as calcium sulphide is a mixture of calcium sulphide (CaS), anhydrous calcium sulphate and small portions of the reducing agents. The material may also contain a very small percentage of hydrated lime. This aggregate of materials is the result of the process of reducing the calcium sulphate.

Calcium sulphide having approximately the above composition which contained from 60 to 65 per cent. CaS has been found to have a high fungicidal value and very slight caustic properties.

Calcium sulphide has been used throughout the spraying season on apples with better results in scab control than the standard spray recommendation based on the use of lime-sulphur, 1 to 40, in the pink, petal fall, and the 3-weeks sprays followed by Bordeaux mixture in the 5- and 7-weeks sprays.

Our tests have shown that calcium sulphide may be used throughout the spraying season on such varieties as the Winesap and Ben Davis. This material, however, should not replace Bordeaux mixture in late summer applications on varieties which are susceptible to bitter rot.

In comparative tests to determine caustic reaction to leaves and fruit of both apples and peaches, calcium sulphide has been found to be less caustic than any of the fungicides in common use at present.

Calcium sulphide must be prepared at a chemical manufacturing plant; it is easy to mix for use in the orchard; it goes into suspension readily; it has better adhering properties than dry-mix, and when stored in a dry place in tight containers it will maintain its original condition indefinitely.

